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PROJECT SUMMARIES

THE UNIVERSITY OF TEXAS, AUSTIN

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INTRODUCTION

The Mechanical Engineering Design Projects Program (MEDPP) at The University of Texas at Austin is the capstone engineering course in the Mechanical Engineering curriculum. Teams of three or four students work together for one semester on industry-sponsored engineering projects; projects are typically sponsored when the sponsoring company does not have the time or resources to solve a problem, wants independent verification of in-house studies, or wants a fresh and uninhibited approach to a design problem.

A number of NASA projects (sponsored by Johnson Space Center, Houston, Texas) were undertaken by student teams in the MEDPP from 1984 through 1987. Additional space projects were sponsored by USRA through the Advanced Design Program in a cooperative effort with the Aerospace and Engineering Mechanics Department at The University of Texas at Austin from 1986 through 1989.

In June 1989, the MEDPP became a participating member in the USRA Advanced Design Program. Four projects were completed during the first semester as a participating member and three projects were completed during the second. The first project discussed deals with the use of satellite data in managing the use of Earth resources. The remaining six projects focus on the design of vehicles and equipment for use in NASA's proposed lunar base. A discussion on the lunar base precedes the project descriptions to clarify assumptions used in the design process.

DEVELOPMENT OF A COMPUTER SIMULATION MODEL FOR PREDICTING VESSEL STATION-KEEPING REQUIREMENTS IN THE GULF OF MEXICO

Satellite data are currently used in a variety of ways, ranging from meteorology and weather forecasting, communications, and monitoring trends in the use of Earth resources. Satellites can also be used to accurately measure the distance from the Earth's surface (either land or water) to the satellite. Knowing the satellite's altitude at all points in the orbit allows satellite altimeter data to be converted into a height above or below a chosen reference level.

One use of satellite altimeter data is for the determination of wave heights in a body of water. Wave height data indicate water speed and direction, so they are useful in tracking major water currents (such as the Loop Current in the Gulf of Mexico) and eddies (large columns of rotating water spawned by major water currents). Wind velocity can also be determined from wave height data; therefore, weather predictions can also be made using the data from satellite altimeters.

Development of a computer simulation model for predicting vessel station-keeping requirements was the goal of this project. An existing code, used in predicting station-keeping requirements for oil drilling platforms operating in North Shore (Alaska) waters was used as the basis for the computer simulation. Modifications were made to the existing code to adapt it for use in simulating conditions found in the Gulf of Mexico (e.g., location of land masses, major water currents, etc.).

The input data to the model consists of satellite altimeter readings and water velocity readings from buoys stationed in the Gulf of Mexico. The satellite data consist of altimeter readings (wave height) taken during the spring of 1989. Each satellite image records wave height data in a 1-km² area of the Gulf of Mexico. In addition, the groundtrack of the satellite repeats every 16 days indicating that data taken during the current orbital pass is 22.5° west of the previous data. Therefore, smoothing techniques were used to account for the spatial and temporal separation of the satellite data in developing a complete input file for the computer model.

Buoys are periodically placed in the Gulf of Mexico to track the direction and speed of the water at various points. Available buoy data is used to verify the water velocity and direction predicted by the computer simulation.

The simulation model predicts water velocity and direction, and wind velocity. Knowledge of these parameters is used to determine vessel station-keeping requirements and weather forecasts. The simulation model can also be used as a resource-minimization tool. Fuel consumption can be greatly reduced through the proper location of vessels in areas of low water velocity.

LUNAR BASE PROJECTS

Background

The concept of a manned lunar base has intrigued mankind for many years. Current mission scenarios call for the establishment of a lunar base beginning soon after the turn of this century. The reasons for establishing a lunar base can be broken down into scientific, resource production, and technology development considerations. The primary lunar resource production effort is focused on the extraction of oxygen from the lunar soil. The production of lunar oxygen (LUNOX) is considered essential for manned exploration of the solar system and beyond.

While the designs were being developed, the following assumptions concerning existing facilities and technologies were made. First, it was assumed that an operational space

station is in low Earth orbit (LEO). A space station is needed as a staging point for the vehicles that will carry crews and cargo to the Moon. Crew cabs and cargo will be carried on lunar landing vehicles resembling the Lunar Excursion Module (LEM) used during the Apollo program. The landing vehicle will be propelled from LEO to low lunar orbit (LLO) using a transport vehicle. Once in LLO, the lunar landing and transport vehicles will separate, with the lander continuing on to the lunar surface.

Second, it was assumed that missions to the Moon will be scheduled approximately six months apart. Using this timetable, lunar cargo landers are required to sit unattended in the lunar environment for long periods of time until the next manned mission arrives to off-load the cargo. Under the present mission scenarios, the lunar landing vehicles are considered expendable until the lunar base becomes manned, at which point the vehicles can be designed with multimission capabilities.

Once the lunar base becomes somewhat developed, launch and landing facilities will be established at some distance from the habitation modules, laboratories, and power plant. This is necessary in order to minimize the danger of landing and launching vehicles in populated areas and because soil particles lofted by the lander engine blast can cause damage to equipment and vehicles.

All the structures and equipment making up the lunar base must be protected from the harsh lunar environment, which includes solar and galactic radiation, extreme temperature fluctuations, periodic micrometeorite impacts, and the constant presence of intrusive and abrasive lunar dust. In order for the lunar base to be a feasible project, innovative designs are needed that will minimize the weight, space, power consumption, manpower, and operation times of the structures, equipment, and vehicles for the lunar base.

Reconfigureable Lunar Cargo Lander

The establishment of a lunar base will require large amounts of equipment and material to be transported to the Moon. During the Apollo lunar missions and in the current lunar base scenario, much of the lunar vehicle is discarded after performing its intended function. The high cost of transporting equipment from the Earth to the Moon makes disposal of any equipment extremely undesirable. Therefore, a lunar landing vehicle that reconfigures into another machine will aid in minimizing the mass to be transported to the Moon during the establishment of a lunar base.

A lunar cargo lander has been designed that can be reconfigured to form the structure over a habitation module; the structure will support the regolith layer used for radiation and thermal protection of the crew and equipment. The lander consists of four legs attached to a central platform. The habitation module and associated internal payload are mounted along one centerline of the platform. Propellant tanks and instrumentation are mounted to the platform in the areas around the habitation module. The lander engines are mounted on the underside of the central platform; the platform

prevents damage to the vehicle components during firing of the engines by isolating them from the engine blast.

After the habitation module, propellant tanks, instrumentation, and engines have been removed from the lander, the legs and central platform are reconfigured such that the lander "straddles" the habitation module. The lander structure will be covered with a fine mesh or blanket and then covered with regolith. The design of the lander also permits multiplexing of the habitation modules in any array desired. Therefore, for every cargo lander sent to the Moon, a payload is delivered and a habitation module (complete with radiation and thermal protection) is produced.

Thermal and Micrometeorite Protection System

As mentioned in the background section, the assumption was made that lunar cargo landers will sit unattended in the lunar environment for long periods of time between successive missions. The lunar cargo lander and payload must be able to endure the lunar environment, which is characterized by large temperature changes and periodic impacts by micrometeorites. A system is required that will protect lunar cargo landers and payloads in these conditions.

A thermal and micrometeorite system that deploys after landing has been designed. The system consists of a composite blanket that is stowed in compact form during transport to the lunar surface. The composite blanket, in the deployed configuration, will provide thermal and micrometeorite protection for the lunar cargo lander. Compressed air "struts" are built into the blanket and are used to deploy the protection system and stiffen the blanket in the deployed position, so that it does not rest against any part of the lander.

Compressed air for the protection system is obtained by boiling off the liquid oxygen (LOX) remaining in the propellant tanks. Air pressure in the struts is maintained using a simple boiler device and valves that regulate the flow of air into and out of the struts. Pressure regulation is required since it is anticipated that the air pressure in the struts will change in response to changes in the ambient conditions.

Once the lander has been off-loaded and the protection system is no longer required, the system can be reconfigured for use as (1) the covering for the structure over the habitation module prior to the addition of the regolith or (2) the exterior covering for a lunar base garage, maintenance facility, or similar structure.

Versatile Lifting Machine with Robotic Capabilities

The establishment and operation of a lunar base will require machines with lifting capabilities for loading and unloading cargo, and robotic capabilities for dextrous operations. A single machine, capable of performing a variety of lifting operations as well as robotic activities, would increase the rate of lunar base development by minimizing the amount of equipment transported to the Moon.

A versatile lifting machine has been designed that is capable of heavy-lift and robotic operations. The machine consists of a chassis, telescoping boom attached to a rotating turntable, robotic manipulator, outriggers (stabilizing legs), and wheels.

The boom is a truss structure composed of three separate sections that telescope to suit the particular operation. The boom is equipped with a hook and cable assembly for general lifting operations similar to cranes on Earth. The robot manipulator is a serial mechanism with 7 degrees of freedom; the manipulator is attached to the end of the boom to aid in attaching the cable to payloads as well as for performing dextrous operations. Attaching the manipulator to the boom allows the manipulator to be positioned within a large work envelope. The manipulator end-effector is a simple three-jaw gripper that permits a wide variety of robotic tasks to be performed.

Four telescoping outriggers are attached to the chassis to stabilize the machine during lifting operations. The outriggers are retracted during transport (to the Moon and on the lunar surface) of the lifting machine. The wheels for the lifting machine are cone-shaped wheels selected for their good performance characteristics in the lunar soil. A hitch is mounted to the lifting machine chassis allowing it to be towed behind a drive vehicle.

Cargo Transport System

A lunar base will likely consist of a number of developed areas (e.g., habitation, laboratory, launch and landing facility, power plant) set apart from each other due to safety considerations. A point-to-point cargo transport system linking the various areas of the lunar base could reduce the power consumption and the manpower needed to move cargo and equipment from one part of the base to another.

A cargo transport system has been designed that consists of an autonomous vehicle that travels on a self-repositioning track. The vehicle consists of an enclosed cargo compartment attached to a chassis; the batteries, drive train, and instrumentation are mounted to the chassis beneath the cargo bay. A serial manipulator is mounted at each end of the vehicle with a conveyor belt running between the two manipulators.

The vehicle is driven by two wheel assemblies located beneath the vehicle. The direction of travel is controlled by guide wheels located on the wheel assemblies that are in contact with a guide rail at the center of each track section. The vehicle drives on a track that is made up of individual track sections connected by a coupling device; track sections are continuously repositioned using the procedure that follows.

As the vehicle moves forward, the rear robotic arm picks up the track section over which the vehicle has just passed and places it on the conveyor belt. At the same time, the forward robotic arm takes a track section off the conveyor belt and attaches it to the track sections already on the ground. The conveyor belt is used to transport track sections from the rear of the vehicle to the forward end.

Direction of travel for the vehicle is determined by the positioning of the track sections. Turning the vehicle is accomplished by laying successive track sections at an angle to the previous sections specified by the desired turning radius. The use of this design will permit energy-efficient transport of cargo and equipment between various areas of a lunar base without a developed roadway.

Design of a Road Construction System for a Lunar Base

The operation of a lunar resource production facility will require the transport of large amounts of raw and processed materials to different areas of a lunar base. In the event that an autonomous transport system (such as the one described above) cannot fulfill the transportation requirements, a system of roads and the associated construction machinery will be required to minimize the energy expended in transporting materials to different areas of the base. A design for a road construction system satisfying these needs is discussed below.

The first step in the project was to determine the road type best suited to the needs of a lunar base. Types of roads considered included concrete, paved, sintered-soil, gravel, and dirt. Consideration was given to the materials and energy required to build each type of road as well as the specific road maintenance requirements and ease of repair. A compacted-dirt road was determined to be the most suitable.

The next step was to identify the machine functions required to produce a compacted-dirt road. The functions identified were excavating and leveling of the regolith, distributing regolith in the excavated roadway, and compacting the regolith to produce a smooth, hard surface. Background research was performed to identify the existing terrestrial machines used to perform these functions as well as any conceptual designs proposed during lunar base studies.

The road construction system selected consists of a main drive unit, a grader attachment, and a vibratory compactor. The main drive unit is a general purpose vehicle that can be used for a variety of operations in addition to its intended use in road construction. Four dome-shaped wheels, a wide wheel-base, and a low center of gravity provide excellent stability for the vehicle while performing any number of operations. A ballast area is provided that can be filled with regolith to increase the vehicle traction forces. A hitch is mounted to the rear of the chassis for towing vehicles.

The grader attachment connects to the front of the main drive unit and the vibratory compactor is towed behind the drive unit. The grader is designed to permit easy adjustment of the cutting blade (e.g., depth of cut, bite angle, and orientation of blade with respect to direction of travel). Vibratory compaction is achieved using a roller and oscillating weight combination. All equipment is designed for operation by base personnel; however, provisions for teleoperation of the road construction system were made during the design of the system.

Design of a Device for Removing Lunar Dust from Material Surfaces

The Apollo lunar missions showed that lunar dust caused a variety of problems ranging from damage to equipment to endangering crew health. The dust was found to be extremely abrasive and to be selectively attracted to a number of materials. The first part of this project was devoted to the characterization of physical properties of lunar dust, and the second to the design of a device for removing the dust from material surfaces.

The dust attaches to material surfaces through mechanical bonding and electrostatic forces. In addition, the dust has a strong affinity for painted metal and plastics. Once the forces holding the dust on surfaces and the materials to which the dust has an affinity were identified, methods for breaking the bonds attaching the dust to a material were proposed.

Since the dust is held to a surface using primarily mechanical and electrostatic forces, three general methods (mechanical, electrostatic, and chemical) for removing the dust were identified. Mechanical methods for dust removal include vibration, scraping/brushing, air jet, and suction (for use in pressurized environments only). Electrostatic methods include both passive (grounding the material surface) and active (preferentially attracting the dust to a stronger electric field). Finally, chemical means for dust removal consist of breaking the bonds using a liquid solution.

The target application for the dust removal device is a spacesuit used in lunar base operations. This application requires that the device work on different materials as well as equipment with irregular geometries.

The final design consists of a brush-blower device designed for use in a nonpressurized environment. A brush, consisting of rows of flexible plastic bristles, is mounted on the end of the device. Gas nozzles are located such that the dust is blown away from the material surface once the brush has loosened

the dust. Small amounts of a waste gas (carbon dioxide) are needed for operation of the device.

The dust-removal device is designed for ease-of-use by personnel wearing spacesuits. Control of the gas flow is achieved using a variable-flow needle valve. In addition, a "dead man" feature is provided that prevents the accidental loss of gas in the event that the device is dropped.

CONCLUSIONS

One of the primary goals of the USRA Advanced Design Program is to foster student interest in space activities and engineering. Working on the space design projects allows students to understand the challenges of designing equipment and vehicles for various missions and environments. In addition, other activities of the USRA give students the opportunity to present their work to an audience outside their university through mid-semester reviews as well as the Summer Conference.

The benefits of the ADP are not limited to the students working on the project. The graduate Teaching Assistant and faculty members involved with the program also benefit through their contact with students, other faculty, and NASA researchers. The ADP undoubtedly creates an interest and excitement in space engineering extending far beyond the university campus.